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Evaluation and selection sunflower hybrids for seed yield under different environmental conditions of Punjab

Rizwana Qamar[1*], Sajida Habib[1], Ejaz-ul-Hasan[1], Ameer Bibi[2], Maria Ghias[1], Shamsa Kanwal[3], Hafiz Saad Bin Mustafa[1], Misbah Zulfiqar[1], Muhammad Anwar[1], Hamna Tariq[2], Shazia Saeed[1] and Ahmad Nawaz[1]

Oilseeds Research Institute AARI, Faisalabad, Punjab, Pakistan; Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, Punjab, Pakistan; Agricultural Biotechnology Research Institute, AARI, Faisalabad, Punjab, Pakistan
*Corresponding author's e-mail:rizwana_pbgians@yahoo.com

Estimation of environmental effects are essential for selection of genotypes for general cultivation at various regions. With this aim a research trial was conducted during spring, 2021 to evaluate suitability and stability of eight sunflower hybrids developed by Oilseeds Research Institute, Faisalabad (ORI, FSD), against two check hybrids at different locations in Punjab. The prime objective of this experimentation was to evaluate and classified sunflower hybrids by multivariate method of principal component analysis (PCA) using the GGE biplot software for their yield. Statistix 8.1 was used to analyze the recorded data and GGE biplot was used for Principal Component Analysis and pictorial demonstration of data. Analysis of variance showed presence of significant variation between hybrids, environments and their interaction. Sunflower hybrid FH-555 showed highest mean yield in Punjab followed by FH-741. The first two principal components present 76% of the total variation. Results indicated that the hybrid FH-740 and FH-751 are best suitable for Multan, hybrid FH-741 and FH-732 for Muzaffargarh, FH-555 for RajanPur, Hysun-33, FH-331, FH-675, FH-648 and S-278 for Faisalabad region. The hybrid FH-741 is highly stable hybrid in yield performance across the environments. The case of this hybrid (FH-741) was submitted in Variety Evaluation Committee (VEC) and got approval for general cultivation in whole Pakistan during 2022. Again the case was submitted in Punjab Seed Council (PSC) and got approval for general cultivation in Punjab during 2023.
Keywords: Genetic variability, micro yield trial, stability, seed yield, statistix 8.1.

INTRODUCTION

Pakistan is far behind in fulfilling local requirement of edible oil of the residents. The import of edible oil reaches up to 85% of total requirement with the import bill of US$ 3.419 billion during 2020-21 while only 15 percent was locally produced (Economic Survey of Pakistan 2020-21). Major oilseed crops grown in Pakistan are cotton, rapeseeds, mustards and sunflower. Sunflower is a potential oilseed crop in the world for edible oil production (Kaya *et al*., 2019; Mahmood *et al*., 2019) that can be used to overcome the shortage of edible oil in the country with 35-55 % oil contents and can be grown twice a year. The agriculture sector of Pakistan is constantly working to increase edible oil production by increasing the area under sunflower cultivation, development and identification of high yielding, stable and well adaptive sunflower hybrids. Government also announced 5000 rupees per acre subsidy for sunflower growers in which 1000 will be given at the time of purchase of hybrid seed and remaining 4000 Rupees at the time of selling their produce. Government also assured to resolve its procurement issues to motivate growers. Oilseeds Research Institute Faisalabad is working on development of sunflower hybrids for different cropping schemes of Punjab. For this purpose, it is very important to evaluate sunflower hybrids at various ecological zones under multilocational trials.

Testing different hybrids under multilocation trials (MET) is of great importance in order to check their adaptability or stability over a wide range of environments. A genotype is regarded to be more adaptive or stable if it holds a high mean yield but, most importantly, its yielding ability exhibits less degree of fluctuations under different agro-climatic conditions (Arshad *et al*., 2003; Dehghani *et al*., 2006). Multilocation trials generate yield data in large amounts often showing genotype by environment interaction. Although environment alone is more effective than their interaction in

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defining the performance of the hybrids but estimation of interaction is also important in terms of selection and approval of hybrids for specific area (Yan 2002).

Although the effect of the environment explains a large percentage of the total variation and the effects of genotype × environment is smaller, these two effects are involved in genotype evaluation and when selecting the top genotypes, the effect of the genotype and the genotype-environment interaction should be considered together (Yan, 2002). Although the effect of the environment explains a large percentage of the total variation and the effects of genotype × environment is smaller, these two effects are involved in genotype evaluation and when selecting the top genotypes, the effect of the genotype and the genotype-environment interaction should be considered together (Yan, 2002). Although the effect of the environment explains a large percentage of the total variation and the effects of genotype × environment is smaller, these two effects are involved in genotype evaluation and when selecting the top genotypes, the effect of the genotype and the genotype-environment interaction should be considered together (Yan, 2002).

The knowledge of this interaction is essential to understand stability in yield. Accomplishment of goals for increase in sunflower growing and production depends not only on the genetic potential of the genotype but also on environmental situation (Dencic *et al*., 2011). GGE Biplot, developed by Yan *et al*. (2000) has made effective interpretation and utilization of MET data in making selection decisions easy for plant breeders. The analysis is based on the graphical representation which helps in addressing many important questions such as the identification of superior cultivars and test environments in a given mega environment. It also presents 'which-won-where' pattern of data which helps in identifying high yielding and stable hybrids for a particular environment (Yan *et al*., 2000; Dehghani *et al*., 2006). The objectives of this study were to use that method to determine the best hybrid for each mega-environment on the basis of seed yield.

MATERIALS AND METHODS

Oilseeds Research Institute Faisalabad has developed eight single cross sunflower hybrids during spring 2019 by using its own locally developed parental inbred lines, these hybrids were evaluated against two check hybrids at six different locations within Punjab dsuring spring 2021 (Table1). Prime objective of this study was to evaluate the effects of different environmental conditions on their productivity and selection of suitable hybrids for specific area. For this purpose six sets of these hybrids were prepared and send to the sunflower progressive growers at six different locations in Punjab. These hybrids were sown three times in randomized complete block design at each location keeping row to row and plant to plant distance of 23cm and 75cm respectively. Two to three seeds per hole were sown to avoid germination related issues. Pre-emergence weedicide pendimethlene was sprayed at good watter conditions to combat the harmful effect of weeds during the early growth phase of hybrids. Extra plants were thinned out at four leaf stage. All agronomic and cultural practices were kept constant at all locations. The crop was harvested at full maturity and seed yield data were recorded carefully. GGE biplot analysis was performed to determine the genotype x environment interaction for seed yield.

Table 1. Name of hybrids, their source and test locations in Punjab.

Sr.	Hybrids	Source	Locations
1.	S-278 (Check)	Syngenta Pakistan	Faisalabad
2.	Hysun-33 (Check)	ICI Pakistan	Sahiwal
3.	FH-555	ORI, FSD	Khanewal
4.	FH-331	ORI, FSD	Multan
5.	FH-648	ORI, FSD	Muzaffargarh
6.	FH-675	ORI, FSD	Rajanpur
7.	FH-732	ORI, FSD	
8.	FH-740	ORI, FSD	
9.	FH-741	ORI, FSD	
10.	FH-751	ORI, FSD	

RESULTS AND DISCUSSION

Breeders are mainly concerned with the development of hybrids and cultivars possessing favorable genetic makeup for

Table 2. Mean seed yield (Kg/Ha) of sunflower hybrids tested at different locations in Punjab.

	Faisalabad	Muzaffargarh	Khanewal	Rajanpur	Sahiwal	Multan	Average (kg/ha)
FH-555	2419	2983	2646	2578	3534	1769	2655
FH-741	2809	2951	2365	2365	2750	2249	2581
S-278	2852	1533	3402	2455	3123	2025	2565
Hysun-33	2364	2211	2534	2500	3432	1986	2504
FH-732	2283	3217	1982	2672	2631	1818	2434
FH-751	2825	2517	2008	1600	3062	2055	2344
FH-648	2768	1851	2352	1893	3266	1756	2314
FH-331	2283	1866	2396	2254	3345	1678	2303
FH-675	2783	1801	2451	2022	3133	1625	2302
FH-740	2488	2049	1962	1809	2175	2176	2110

productivity and stability across environments. Stability is the ability of hybrids to react at various environmental conditions. Criteria for stability should not only be the seed production, its good performance should also be documented across different environmental conditions (Sial *et al*., 2000).

Table 3. Mean squares for hybrids, locations and their interaction.

Source	Degrees of freedom	Mean squares
Replications	2	72156
Hybrids	9	498435**
Locations	5	4391279**
Interaction	45	457842**
Error	118	10303

Mean yield performance of eight sunflower hybrids at six locations are presented in Table 2. Average seed yield of sunflower hybrids varied from 2110 to 2655 kg/ha. The sunflower hybrid FH-555 shows highest average yield with maximum yield at Sahiwal district followed by FH-741 with maximum yield at Muzaffargarh district. Combined analysis of variance for achene yield of sunflower hybrids confirms the presence of variation among 10 sunflower hybrids grown under six environmental conditions (Abdelsatar *et al*., 2020). Total variation was divided into components to quantify the role of genotypes (hybrids) environments (locations) and their interaction (G X E) (Table 3) Which showed that the environment has a strong role in defining the yield of sunflower hybrids (Bishwas *et al*., 2021, Marinkovic *et al*., 2011). ANOVA showed highly significant difference in hybrids, location and their interaction which clearly depicts the presence of variation among hybrids, locations as well as their interaction (Ansarifard *et al*., 2020). Radic *et al*., 2020 also find the noticeable effect of environments on the performance of sunflower hybrids. contradictory behavior of hybrids in different environmental conditions are also reported by (Ahmed and Abdella 2013). Generally, first two components clarify the worth of studied variables in total variation but the first component has more significance due to the contribution of maximum variation to data (Silva & Padovani, 2006). First two Principal components showed maximum variation of 76% (Fig.1). GGE biplot analysis draws a meaningful picture about the interaction of genotypes with environment and classify them for yield and oil contents very efficiently (Leite and Oliveira, 2015). Selection of genotypes by Genotype x Environment interaction, using GGE biplot shows the stability of hybrids in different environments (Yan and Tinker, 2006).

One of the most attractive features of a GGE biplot is its ability to show the which-won-where pattern of a genotype by environment dataset. Which won where identifies the best appropriate hybrids for each environment. Polygons are formed by joining four hybrids drawing margins while six hybrids are inside the shape. Red rays are drawn perpendicular to the sides of polygon marking a specific environment/location or their group. In this study, four rays divided the polygon into four sections (Yan *et al*., 2007). The genotypes that fall in these sections are close to each other and have highest yield for that specific location. Figure 2 indicated that the hybrid FH-740 and FH-751 are best match for Multan district, the hybrid FH-741 and FH-732 for Muzaffargarh, FH-555 for RajanPur, Hysun-33, FH-331, FH-675, FH-648 and S-278 for Faisalabad region. Biplot is an amazing technique which is utilized by many researchers to clear the concepts of Genotype x Environment interaction and adaptation of genotypes to specific area. Actually it helps in visual assessment of both genotype and genotype x environment interaction, classifying sunflower genotypes depending on their performance (Ullah *et al*., 2007).

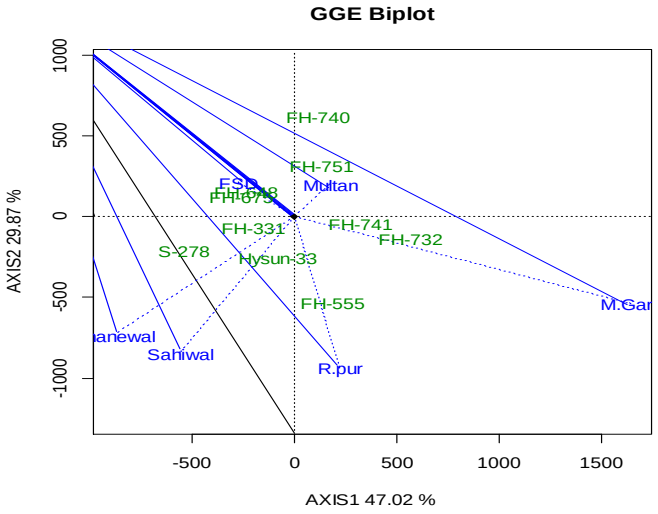

Figure 1. Graphical presentation of GGE biplot analysis showing variability in hybrids and locations.

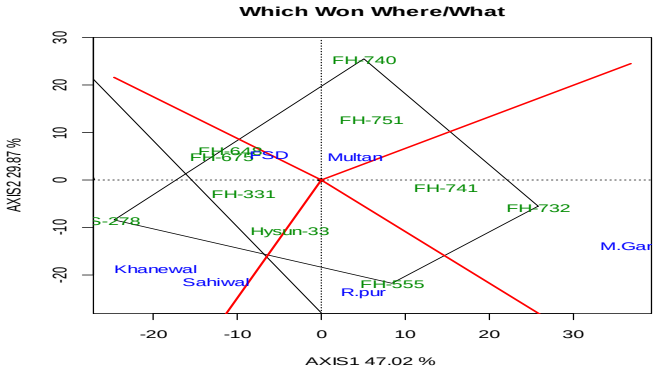

Figure 2. Polygon view of GGE Biplot method for determining the performance of appropriate hybrids at six environments in Punjab.

Brief description of relationship between different locations is presented in Figure 3. The connected lines at the origin of a plot represent environment vectors. The angle between

environment vectors represents the correlation coefficient between studied locations. If the angle between two vectors is 180˚ the relationship is negative (−1), the angle equal to 90° depicts no connection and when it is lesser than 90°, positive relation (+1) between two environments are acknowledged. By formulating the relationship between environments, comparable environments can be recognized and omitted in research experiments on assessment of stability for a number of years (Yan & Kang, 2003; Yan & Rajcan, 2002). In this figure, the smallest angle is between the environment vectors of Khanewal and Sahiwal. Districts RajanPur and Muzaffargarh also had a small angle for environment vectors which again showed the similarity in their environmental conditions. So, these locations can be placed in a single group. Largest difference in environments has been observed between Rajanpur and Khanewal.

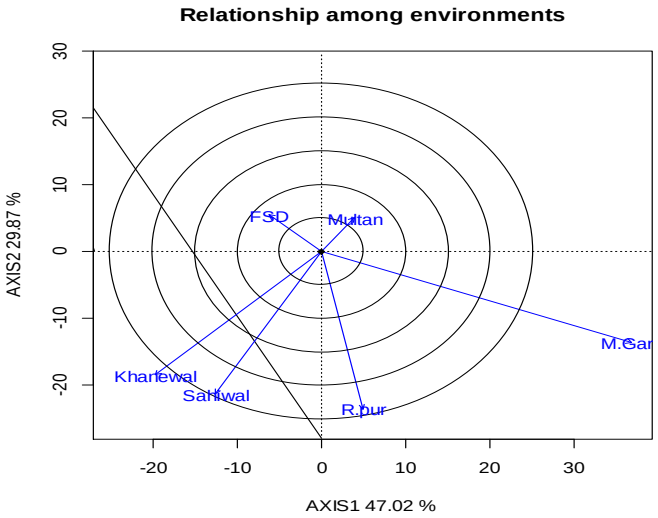

Figure 3. Interrelationship between six environments.

The ranking of hybrids by their mean and stability is presented in the Figure 4. Estimation of stability in yield of any genotype is very important because stable cultivars or hybrids can be grown on wide agroclimatic conditions and gives sustainable production (Moghaddam and Pourdad 2011). The line passing through the biplot origin from upper left to the lower right represents the average environmental axis, which shows the mean of first and second principal component scores of all environments. The line which passes from the mean environmental axis from the origin represents the stability of genotypes. The genotypes that are away from the stability axis showed higher variation due to environment and thus reduced stability (Yan and Kang 2003). This plot helps in the selection of hybrid which has higher stability in mean yield of hybrids across various locations (El-Harty *et al*., 2018). In this study FH-741 is the most stable genotype across all environments. On the other hand, the hybrid FH-555 has the higher mean yield as it is located near the mean environmental axis but away from the stability axis which means this hybrid can be selected for specific environment like it performs best at Rajan Pur and can be approved for general cultivation at the specific environment. The genotype or hybrid which should be gone for selection should be best in terms of performance and consistency at different locations (Yan *et al*., 2007) but in real world this may not happen but this helps to generate the most suited genotypes or hybrids for multiple environments (Mitrovic *et al*., 2012).

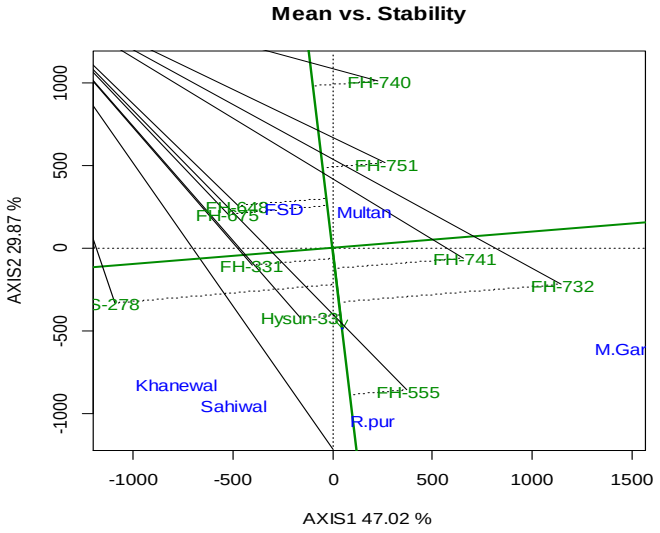

Figure 4. Genotypes stability and GE interaction at different locations.

Conclusion: Oilseeds Research Institute Faisalabad is sole Institute in Punjab working on sunflower hybrid program. Each year new combinations were developed and tested against check hybrids. A multilocational evaluation was conducted during 2021 to select the suitable sunflower hybrids for various ecological zones of Punjab. Variance analysis suggested the variable response of hybrids, environments and their combination. Highest mean value for seed yield was displayed by the hybrid FH-555 followed by the hybrid FH-741. FH-741 is found to be the most stable hybrid across the environments. This hybrid was also approved by VEC and PSC for general cultivation in whole Pakistan and Punjab respectively.

***Authors contributions statement*:** Rizwana Qamar, Sajida Habib and Ejaz-ul-Hasan conduct the research and collected data from different locations and write the manuscript. Ameer Bibi, Maria Ghias and Shamsa Kanwal analyze the collected data, Hafiz Saad Bin Mustafa, Misbah Zulfiqar and Muhammad Anwar proof reads the manuscript. Hamna Tariq presents the data in graphical form. Shazia Saeed and Ahmad Nawaz helps in statistical analysis and finalization of draft.

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***Ethical Statement*:** This article does not contain any studies regarding human and animals.

***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published **before** and is not currently being considered for publication elsewhere.

Code availability: Not applicable.

***Consent to participate*:** All authors participated in this research study

***Consent of publication*:** All authors' submitted consent to publish this paper.

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